AIRCRAFT

ABSTRACT

The capabilities of the United States aircraft industry make it one of the essential foundations of the economic, political, and military elements of U.S. national power. Nevertheless, the events of 2001 significantly diminished the industry's vitality. Still leading U.S. business in export dollars, the industry has been forced to look for new markets as worldwide aircraft sales have dropped. Because the U.S. national security depends so heavily on this industry, the U.S. government provided support to weakened sectors – notably, the commercial air transport sector – that helped forestall a grave diminution of capability. As the U.S. economy emerges from the 2001 recession, so, too, will the aircraft industry begin to recover. In the meantime, the European aircraft market has experienced similar setbacks, but recent aircraft orders have restored vigor to their commercial transport sales. U.S. and European aircraft manufacturers continue to vie for market dominance, but only persist in maintaining relative parity, even as they find increasing collaborations to be in the interests of both. Given these circumstances, and without cooperative strategic planning by public and private organizations, the aircraft industry faces an uncertain future.

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Boeing Military Aircraft and Missile Division, St. Louis, MO and Long Beach, CA
Lockheed Martin Corporation, Crystal City, VA
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INTRODUCTION

Even after the shocks of 2001, the aircraft industry remains a major contributor to the U.S. economy and national security. In 2001, total sales by U.S. manufacturers topped $146 billion.[1] The export portion of sales (approximately $55 billion in 2000) makes the aircraft industry one of the few areas where the U.S. has been able to maintain a strong favorable trade balance. Also in 2001, the industry provided jobs for nearly 800,000 Americans, half of whom worked in production. However, this figure is the lowest the industry has seen in four years, with the greatest job loss experienced by hourly production workers. Large-scale layoffs have forced thousands to seek other employment and left only the most senior workers employed in some heavily unionized shops. Workforce retrenchment may leave the industry to cope with an aging workforce, unable to rehire or replace workers when demand rises.

In spite of this downward trend, the aircraft industry is a leader in high technology. Unmanned aerial vehicles, supersonic and stealth capabilities and tiltrotor development top a long list of U.S. accomplishments that the aircraft industry has brought to fruition.

This report focuses on four sectors of the aircraft industry: commercial transport and cargo aircraft; military fixed-wing aircraft; rotorcraft (helicopters and tiltrotor aircraft); and aircraft jet engines. Two companies dominate the commercial aircraft business, Boeing and Airbus. Four companies dominate the military fixed-wing market, Boeing, Lockheed Martin, BAE Systems, and European Aeronautic Defence and Space Company (EADS). The rotorcraft segment consists of the three dominant U.S. manufacturers, Bell Helicopter (Textron), Boeing, and Sikorsky Aircraft (United Technology Corporation) and their two principal European competitors, EADS Eurocopter (a partnership of Germany and France) and Agusta Westland (a partnership of Italy and the United Kingdom). The four primary international aircraft engine producers are paired into two U.S. companies, General Electric (GE) and Pratt & Whitney (P&W), and two European companies, SNECMA in France, and Rolls-Royce in the United Kingdom, which includes Rolls-Royce Allison in the U.S.

EXECUTIVE SUMMARY – Impact of September 11, 2001

Although the aircraft industry was already experiencing declining growth due to recession, the events of September 11 sharply increased the slowdown. The full cost of the terrorist attacks on the aircraft industry is still being calculated, but the initial assessment is bleak. The first-ever grounding of all civil aircraft in the U.S. and subsequent flight restrictions further destabilized the already-depressed industry, rippling from airports and airlines to hospitality and tourism. The air transport sector employs about four million persons worldwide, and figures indicate that more than 200,000 have already or will soon lose their jobs.[2] Airlines have abandoned routes and cut back others, resulting in about 20 percent of U.S. passenger aircraft being placed in storage. Industries structured on just-in-time supply relying on air cargo faced work stoppages, demonstrating the vulnerability of the supply chain. The attacks instilled anxiety in many people that kept them from flying. Future profitability will depend on whether and when the public decides it is safe to fly.

The only industry benefit derived from the tragic events of September 11 might be to the military fixed-wing sector, where a volatile market has shown signs of

resurgence. With the advent of the war on terrorism, military aircraft development and procurement programs are currently trending towards growth. While there is still debate over the number of different models projected (F-22 *Raptor*, F/A-18E/F *Super Hornet*, and F-35 *Joint Strike Fighter*), the future of military aircraft looks brighter in the near term than it has in the last decade. The increase in operations tempo also produced service contracts for the industry (which will offset some of the losses in the civil sector) and underscored the need for additional C-17 strategic transports and aerial tankers.

The rotorcraft industry faces a small but stable market with too many competitors, but we believe emerging homeland security requirements will spur sales of rotorcraft. Likewise, unmanned aerial vehicles (UAVs) offer an intriguing range of possibilities associated with new defense roles. Successful operations by UAVs (armed and unarmed) in Afghanistan have spurred interest that is being rewarded with greater funding and scrutiny.

Finally, the post-September 11 environment has left the aircraft engine sector in precarious territory in the near-term, with the sales of commercial aircraft stalled and military sales unable to make up the loss. Nevertheless, the engine sector retains a fundamental capacity that will assure U.S. strategic capability remains sound.

Overall, the U.S. aircraft industry is struggling in the wake of the attacks of September 11. The appalling events of that day highlighted the vital role that the industry plays in the economic framework of our nation. Hopes of recovery are pinned on partnerships, new technologies and improved services to provide worldwide lifecycle support to customers. In the interim, the federal government's bailouts have temporarily eased some of the airlines' losses, but with prospective subsidies unlikely, the aircraft industry faces an indeterminate future.

COMMERCIAL FIXED-WING AIRCRAFT

For the purposes of this report, commercial fixed-wing aircraft include medium and large passenger and cargo aircraft of greater than 100-passenger capacity.

Current Condition. Arguably, no other industry was so immediately and drastically affected by the September 11 terrorist attacks as the commercial air transport industry. Along with the revenue lost as a result of the nationwide grounding of all aviation activities, all forecast models of passenger projections and aircraft purchasing requirements have been invalidated, which translates to a cloudy near term market forecast for aircraft manufacturers and related industries.

Airline revenue, historically, has been cyclical and was already declining before September 11, with an estimated industry wide net loss of $3 billion. Despite compensation from the $15 billion Air Transportation Safety and System Stabilization Act[3], major airlines are still estimated to post a net loss of $7 billion for 2001.[4] Additional operating challenges, including increased insurance rates and aircraft modification costs, will serve to drive the ledger further into the red. For example, the Federal Aviation Administration (FAA) estimates that U.S. airlines will spend up to $120 million over the next 10 years to comply with new cockpit door security requirements.[5] The industry average breakeven load factor of passengers per available seats is 77 percent, and the average load factor rate for 2001 fell to 71.3 percent.[6] Even more troubling is the accompanying reduction in labor that mirrors these complications. Although gradual recalls are in progress, as of December 2001, the major airlines were

forced to lay off a total of 80,300 workers across the entire spectrum of the airline industry, largely as a result of the September 11 attacks.[7]

The demand for aircraft historically follows the air travel rates, and this rate drastically abated after the attacks of September.[8] In July 2001, Boeing had reduced their projected 2002 production numbers from 530 to 510 aircraft due to the cyclical airline slowdown, but at the end of the year they were forecasting as few as 400.[9] We estimate that it will take a year for the airlines to recover and another year before they start ordering airplanes in increasing numbers again.

Challenges. The Boeing Company is the world's leading aerospace company and is the largest U.S. exporter with 2001 company revenues reaching $58 billion. Sixty percent of Boeing's total revenue is derived from their Commercial Aircraft Division and today there are over 12,000 Boeing aircraft still in service, representing 75 percent of the world's fleet.[10] Boeing clearly dominated Airbus in 2000 aircraft delivery, accounting for 63.8 percent of the total, as compared to 36.2 percent for Airbus. However, the backlogged orders paint a different picture. In 1997, Boeing topped Airbus with orders for 1,660 airplanes compared to 727 for Airbus. Four years later, in July 2001, the scales changed with Airbus compiling 1,706 orders to Boeing's 1,471.[11] For the first time in the battle between the two companies, Airbus had the edge.

Boeing appears to be in the final stages of a corporate transformation toward its vision as a global enterprise for aerospace leadership. 2001 saw the corporate headquarters relocate from its Pacific Northwest roots in Seattle to the more urban and "business-centric" venue of Chicago, a move presumably aimed at dispelling heritage and legacy prejudices in favor of more strategic, revenue-based decision making.[12] It is important to note that although Airbus has gained considerably in market share, its operating margins appear to be under five percent, while Boeing's have returned to the two-digit range.[13]

Conceived in 1970 to overcome American dominance in the aircraft manufacturing industry, Airbus has maintained a single strategy for the last six years: overtake Boeing as the world's leading aircraft manufacturer. Amidst accusations of excessive government subsidies supporting its growth, Airbus now finds itself in a position to do exactly that. It is of little dispute that European governments collectively bankrolled the development of Airbus, but the Europeans countered that the U.S. had provided similar funding for its industry giants under the heading of "Research and Development." As Airbus began to present more credible competition to U.S. aircraft manufacturers in the 1980s, the western side of the Atlantic became more vocal in its accusations. The Clinton administration responded by proposing government assistance to the industry by establishing a consortium called Aerotech, funded with $10 billion to subsidize the industry, more specifically to assist struggling McDonnell Douglas.[14] But it was Boeing, and not the U.S. government, that aided McDonnell Douglas by purchasing the company in 1996. Ironically, this move may have served to secure Airbus' future, as U.S. airlines were not willing to accept a single source market.

Although earlier Airbus passenger models such as the A300 generated little profit for the company, later models had much greater success. In 1993, Airbus had sold fourteen A340s as compared to only two 747s from Boeing. Nevertheless, Airbus strategists didn't think the A340 alone could compete against the 747 and consequently turned their attention to development of a 550-plus seat super jumbo aircraft later to be

designated the A380. There were 151 Boeing 747s on order in mid 1997, but at the close of 2001, that number had dropped to 77.[15] Clearly, the A380 is starting to exert some pressure on Boeing as airlines have ordered 97 of the soon to be produced super jumbo aircraft.

Outlook. The slow recovery of the commercial airline sector will continue to plague aircraft production at least through 2004 and most probably beyond. 2003 will likely be the trough, with Boeing already forecasting a delivery range of only 350 – 400 aircraft in 2003, compared to the 527 deliveries in 2001.[16] Airbus is forecasting approximately the same production numbers for 2003, but some analysts say that number may be closer to 200.[17] This projection will be further clouded by what we see as an inevitable merger of competing airlines. American Airlines has merged with TWA and a proposed merger between United and US Airways was seriously considered but eventually rejected by regulators out of fear that the combined airline would impede competition.[18] We believe that industry consolidation will likely be stimulated by the federal government's bailout package. $10 billion of the $15 billion bailout package is set aside for loan guarantees from the federal government. Disbursal of these funds is at the discretion of a government board set up to handle loan requests by airlines. Rejected loan requests from struggling airlines would eliminate any options other than consolidation.

Complicating the manufacturing industry forecast further is the rapidly growing number of aircraft being "parked" in the desert. As air travel growth slowed in early 2001, the number of aircraft in storage reached a record high of 1,200. However, since September 11, an additional 950 aircraft have entered preservation lots, including newer models from both Boeing and Airbus that are still in production today. Most analysts predict that as many as 700 of these aircraft will reenter service, representing an entire year of normalized aircraft production and likely depressing future production.

Future market analysis has produced a distinct fissure between Boeing and Airbus product development strategies. Airbus contends that strong passenger and freight growth rates, coupled with airline alliance trends and geographic concentration, translate to a requirement for larger aircraft. Boeing counters that airline demands for flexibility and the availability of new long-range aircraft will result in route fragmentation, thereby decreasing the requirement for large aircraft.[19] Boeing's strategy is the development of the Sonic Cruiser, a revolutionary aircraft designed to fly just below Mach 1 and reduce air travel time by up to 20 percent, with a fuel efficiency rating equal to or better than the newest aircraft in production today.[20] It will afford practical and economic point-to-point travel, eliminating passenger inconvenience from hub transfer complications. This drastically counters the Airbus solution centered on the development of the A380 to accommodate the anticipated passenger growth rates and erode the Boeing monopoly of the jumbo market with its 747 variants. The Airbus A380 is projected to enter service in late 2006.

Shortly after the September 11 attacks, Boeing announced a plan to reduce its commercial aircraft manufacturing division by as many as 30,000 employees to adjust to the anticipated decrease in production requirements. This could indicate that development of the Sonic Cruiser may be delayed beyond the 2008 production target. To date, Airbus has not reciprocated with a massive layoff plan, but has instead announced that it will cut the equivalent of 9,400 jobs by reducing overtime and shift work hours.[21] We believe that layoffs at Airbus are inevitable and estimate that the initial cut will be in

the 2,000 range. Recovery from labor reductions of this magnitude will present both companies with significant challenges. As the dismissed workers seek alternate, more secure employment, the ready pool of replacement labor for future production increases will be severely diminished. Furthermore, those that are senior enough to retain their jobs represent an aging work force, a potential concern if replacement labor cannot be found.

In the summer of 2001, the FAA forecasted that by 2010 there would be one billion annual airline passengers. In March 2002, FAA was forced to revise this milestone to three years later.[22] This translates into lower than anticipated aircraft orders. The greatest growth will likely emerge from the Asian market where Boeing currently seems to have an edge, most notably in Japan. Boeing is already offering partnerships to Japanese firms for the construction of the Sonic Cruiser. Mitsubishi Heavy Industries, Kawasaki Heavy Industries, and Fuji Heavy Industries have played key roles in the production of the airframes for Boeing's two big twin-engine airliners, the 767 and the 777.[23] We believe that Boeing's partnerships in the Asian theater will serve as an effective strategy in the challenge for market share. However, since most of the Asian populace reside in close proximity to existing airline hub cities, the passenger capacity offered by the A380 may be attractive to Asian carriers. Furthermore, Airbus has recently announced agreements with four Japanese manufacturers to produce critical structural components for the A380, thereby introducing monetary incentive in Japan to compete with Boeing.

We predict that eventual aircraft demand, coupled with political intervention for regional economic stability, will provide an opportunity for both Boeing and Airbus to prosper in the commercial air transport industry. However, the question of industry dominance will be answered by more than just strategic assessment and differing philosophies on the future of air travel requirements. The A380 relies on cooperation of international airports for adaptation. Service to individual airports will require an estimated investment of between $2 and $6 billion to upgrade runways, taxiways, and terminals in order to accommodate the aircraft.[24] Additionally, the recent escalation of passenger frustration and inconvenience with security checkpoint procedures will be amplified by the obvious complications inherent in deplaning more than 550 passengers from one aircraft. Airbus is, however, confident in the success of the A380 and has devoted the majority of its research and development funding for this project, which raises the concern that Airbus may be sacrificing the modernization of its current models in favor of the super jumbo strategy.

Boeing's Sonic Cruiser is projected to reduce travel time as much as two hours on a flight between New York and Tokyo and avoid the hub and spoke concept of forcing passengers to make connections prior to reaching their destination. However, this aircraft presently exists in concept only and faces some very significant engineering challenges prior to actual production. As society's focus on speed and efficiency continues, we consider it plausible that the amenities inherent in the Sonic Cruiser will be more appealing to the customer willing to pay premium prices than the high passenger volume offered by the Airbus 380. Given the exceptionally thin profit margins under which airlines are forced to operate, the final answer will be settled by cost. If the Sonic Cruiser can perform to its advertised specifications and attract sufficient passengers, it may

transform the industry and once again reduce Airbus to a follower status, embroiled in a perpetual race to catch Boeing.

MILITARY FIXED-WING AIRCRAFT

The military, fixed-wing sector of the aircraft industry includes strike, fighter, bomber, air mobility, special-mission and trainer aircraft designed, built or modified for military unique mission requirements.

Current Condition. The end of the Cold War and low procurement spending by the U.S. and Europe throughout the 1990s resulted in a prolonged sales slump for this sector. Total U.S. military aircraft sales fell in 2000, dropping $2.1 billion from 1999 numbers to $34 billion, largely due to reductions in exports.[25] U.S. military aircraft production in 2000 also fell to its lowest level in at least 50 years, dropping to less than two-thirds of the 1999 level.[26] U.S. manufacturers in 2000 delivered 233 aircraft, as compared to 359 in 1999.[27] Total exports declined by 58 percent and those exported via Foreign Military Sales (FMS) fell to their lowest level on record.[28] However, recent U.S. decisions to proceed with the F-35, F-22 and F/A-18E/F programs, combined with increasing Department of Defense (DoD) spending in response to the September 11 terrorist attacks, have helped buoy the industry.

The sector has benefited from the war on terrorism. The terrorist attacks of September 11 appear to have at least partially muted congressional concern over projected costs for simultaneous acquisition of multiple systems. The increase in operations tempo also produced service contracts for the industry (which will offset some of the losses in the civil sector) and underscored the need for additional C-17 strategic transports and aerial tankers. However, because the war on terror will consume additional funding for security and intelligence efforts, analysts are cautious to predict a long-term recovery. While successful operations by UAVs received wide publicity, in the future, greater use of unmanned systems will likely reduce manufacturers' profit margins because of the lower, per-unit costs of production for unmanned versus manned systems. The shift to unmanned systems could also accentuate existing overcapacity. These factors will lead to further consolidation in the industry.

Two corporations – Lockheed Martin and Boeing – have emerged from a series of consolidations to dominate the design and manufacture of U.S. military fixed-wing aircraft. Roughly half of Lockheed Martin's income is derived from DoD contracts, while Boeing relies on DoD for approximately 21 percent of its annual business.[29] Northrop Grumman, third in the U.S. market, remains as the major U.S. subcontractor and partner to Lockheed Martin and Boeing. In Europe, BAE Systems and EADS are the industry leaders, prime competitors, and occasional partners to U.S. firms.

Lockheed Martin's Aeronautics Company, in concert with Boeing's Military Aircraft and Missile Systems Division, produces the F-22, with Lockheed Martin's production share of the workload at approximately 67 percent and Boeing's at 33 percent. The U.S. Air Force (USAF) currently plans to procure enough F-22s to fill mission requirements, subject to congressional support and funding, with production projected to run through 2014. Under current U.S. policy, the F-22 will not be offered internationally, limiting prospects for a long-term revenue stream through exports.

In October 2001, Lockheed Martin also won the $200 billion Joint Strike Fighter (now designated the F-35) competition and intends to produce the F-35 in partnership

with Northrop Grumman and BAE Systems. According to current plans, Lockheed Martin will produce 1,763 conventional variants for the USAF, 480 carrier-capable variants for the U.S. Navy (USN), and 609 short takeoff and landing variants for the U.S. Marine Corps (USMC) and Britain's Royal Air Force (RAF). Lockheed Martin is marketing the F-35 internationally and has generated significant interest in Europe and Asia. However, full rate production will not begin until 2008, leaving Lockheed Martin Aeronautics' fighter assembly line dependent on F-16 *Fighting Falcon* (and eventually F-22) deliveries in the interim. New F-16 production for the USAF is currently limited to attrition replacement, with production scheduled to end in 2012. Lockheed Martin also performs modification work for the USAF's existing F-16 fleet and, in 2002, was awarded an estimated $12 billion service contract from the USAF as part of the Falcon 2020 program. This program includes engineering services and technical support, FMS-directed repair and return, contractor support, acquisition development and integration, and supplies in support of the F-16 weapon system for a 23-year period. The service contract supports FMS to Belgium, Denmark, Netherlands, Norway, Bahrain, Egypt, Greece, Israel, Jordan, Korea, Portugal, Singapore, Taiwan, Thailand, Turkey and Venezuela.

Lockheed Martin's transport programs include the C-130J *Hercules*, C-5 *Galaxy* and C-27J *Spartan*. Unusual in that it was developed with commercial financing, the C-130J is the latest model in the C-130 line. The USAF plans to purchase 150 C-130Js to replace its 30-year-old C-130E fleet.[30] While other customers include the U.K., Australia, Italy, Denmark, U.S. Marine Corps, and U.S. Coast Guard, the overall market for the C-130J remains stagnant, and export sales will likely be constrained by competition from the Airbus A400M. European Union (EU) customers are influenced towards the latter by continental loyalties and defense budget constraints. The C-5 remains critical to movement of oversized cargo, but its low mission-capable rates have contributed to shortfalls in meeting DoD's mobility requirements.[31] C-5 fleet modernization consists of an Avionics Modernization Program and a Reengining Program.[32] The twin-engine C-27J is the result of Lockheed Martin's partnership with Italy's Alenia Aerospazio. As a result of this alliance, the Italian Air Force has selected the C-27J. While future sales are proving difficult to win, Lockheed Martin recently announced that Greece is buying 12 C-27Js, with an option for 3 more.

Boeing continues to produce the F/A-18E/F for the USN and, as currently planned, production will continue through 2014. Boeing also produces the F-15E *Strike Eagle* for the USAF, but at a rate of approximately one per quarter. South Korea recently selected the F-15K as part of its $4.5 billion program to procure 40 new fighters.[33] Boeing, in concert with BAE Systems, is manufacturing the last production lot order for 234 T-45 *Goshawk* training jets for the USN and the Royal Air Force.[34]

Boeing's C-17 is replacing the C-141 *Starlifter*, which the USAF is retiring as its core transport. The USAF has agreed to buy 120 C-17 *Globemaster III*s and plans to order 60 more, which will keep the production line operating through 2007. The U.S. Transportation Command has called for procurement of an additional 42 C-17s, which could extend production through 2011.[35] The U.K. recently leased four C-17s to meet its short-term strategic airlift requirement, marking the first export order for a Western strategic transport.[36] Boeing is pushing for additional export sales and for possible lease of a BC-17 commercial variant to outsize cargo users.[37] The USAF is studying Boeing's

KC-767 tanker, a derivative of the commercial 767, as a proposed solution to its requirement for an initial lease of 100 new aerial refuelers to replace aging KC-135E *Stratotankers*. If selected, Boeing may begin deliveries in 2005 and the USAF will begin soliciting bids for the next 100, in which Boeing will again compete against the Airbus A330-200 tanker derivative.[38]

Northrop Grumman is the developer of the Global Hawk and Pegasus UAVs. In the 1990s, the company reacted to the sharp reductions in U.S. defense spending and aircraft procurement by transforming itself from primarily a producer of military aircraft to a defense electronics, systems integration and information technology company.[39] Northrop Grumman no longer seeks a position as a prime contractor/integrator of fixed-wing manned aircraft (as it is for the B-2 *Spirit* and F-14 *Tomcat*). However, the company retains significant military aircraft design capabilities while producing and integrating sensors and information systems on multiple platforms, including the E-3 *Sentry* (AWACS), E-8 *Joint Stars*, E-2C *Hawkeye*, C-17, F-16, F/A-18E/F, F-22 and F-35.

In Europe, BAE Systems will manufacture 680 Eurofighter *Typhoons* through 2007 and participate in F-35 production with Lockheed Martin. BAE Systems, a shareholder in Saab, is marketing the J-39 *Gripen* aircraft as a low cost fighter alternative to Lockheed Martin's F-16. BAE Systems is also developing a prototype to replace the British *Tornado* fleet, currently scheduled for retirement by 2017. Dassault will manufacture approximately 250 *Rafales* for the French Air Force and Navy.

Overcapacity remains a characteristic of the military fixed-wing sector. For example, Lockheed Martin now produces the F-16 at a rate of seven per month using one work shift. A three-shift schedule could increase production to about 11 aircraft per month, which is still far below the 24 aircraft per month production level of the 1980s. Boeing annually produces 16 C-17 transports, but has sufficient tooling for production of 18 aircraft per year and sufficient plant space for production of 29 aircraft per year. In sum, the U.S. prime manufacturers have significant capacity to surge production, but the effort would require investment in additional tooling, training of additional workers, and support of lower tier vendors in supply and aircraft component manufacture.

Challenges. Challenges to the military, fixed-wing aircraft sector include reduced long-term demand, fiscal constraints, and foreign competition. Since the mid-1980s, DoD's annual purchases of fixed-wing aircraft have dropped from 400 to about 100 per year, and this market is likely to remain flat beyond 2015.[40] Even in the midst of the war on terrorism, Congress remains concerned about simultaneously funding three fighter programs. DoD has responded with transformation plans that may require reexamination of currently planned acquisitions. As yet, nothing has been decided, but the question remains open as to future roles and acquisition of manned platforms.

Worldwide, excess production capacity has led to fierce competition among aircraft producers. U.S. and European producers are battling to establish a long-term foothold in what will likely be one of the last new markets available to this sector – the new NATO members of Central Europe. While FMS remains key to utilizing excess capacity and maintaining the economic viability of U.S. producers, U.S. firms are having difficulties keeping up with European competitors in terms of offsets and EU cooperation. For example, Hungary and the Czech Republic recently selected the *Gripen* over Lockheed Martin's F-16. Hungary cited Sweden's offset[41] proposals – which

covered 100 percent of the lease cost – as one of the main reasons for its selection of the *Gripen*.[42] U.S. fighter exports are also constrained by the "production gap" between existing fighters, such as the F-16, and future export systems like the F-35. This gap provides a marketing window for foreign competitors to meet requirements of customers who need fighter systems now and demand "state of the art."[43] Finally, in air mobility, European efforts to market the Airbus A400M are significant, though some of the involved governments have not yet given their final approval for aircraft purchases.

***Outlook*.** DoD remains committed to funding the acquisition and life-cycle maintenance costs necessary to sustain this sector. The lean times the sector faced in the 1990s appear to be reversing as a result both of DoD's efforts to recapitalize tactical aviation and the increasing post-September 11 defense budgets. But it is too early to determine how long the recovery will last and, in fact, DoD recently renewed its commitment to closely examine the need for the F-22, V-22 *Osprey* tiltrotor, and RAH-66 *Comanche* helicopter programs. Furthermore, Congress has expressed concern that DoD is headed for a fiscal "train wreck," as all four services jump on the transformation bandwagon but funding falls short. Several costly, fixed-wing projects – including F-22 and V-22 *Osprey* full rate production, F-35 development and the replacement of EA-6B *Prowler*, P-3 *Orion*, E-8 and KC-135 fleets – are simultaneously reaching a budgetary critical mass.[44]

America's top three players in this sector are taking different approaches to the future. Lockheed Martin Aeronautics Company is concentrating on service contracts and international sales of the F-16 through 2012, F-22 sales to the USAF through 2014, and F-35 sales beyond. Holding the strongest position, given current popular and congressional support for the military and the war on terrorism, Lockheed Martin is moving staff and resources to speed development of unmanned reconnaissance and attack aircraft after the success of experimental models in the Afghanistan war. The U.S. deployment of Predator, Global Hawk and other unmanned systems in Afghanistan triggered increased international interest in using the aircraft for combat and surveillance roles. Given these circumstances, development of unmanned aircraft will rank among the company's top three priorities, along with continued search for the next technological leaps, and producing the F-35 and the F-22.[45]

Boeing is also concentrating on service contracts. Boeing plans to triple sales through its military aerospace servicing business over the next five to ten years as the U.S. maintains its aging planes. Military aerospace servicing accounted for 22 percent, or $2.75 billion, of the $12.5 billion sales at Boeing's military aircraft and missile systems unit in 2001 and is expected to reach $8.25 billion within a decade. Boeing is also focusing on sustaining future military business after the terrorist attacks slashed orders for commercial jetliners. In air mobility aircraft, Boeing will complete C-130 avionics upgrades, may build KC-767 tankers through at least 2005 and C-17s through 2011. In fighters, Boeing will build the F-15K for South Korea through 2009, perform work on F-22 production through 2014, and produce the F/A-18E/F through 2014. However, the loss of the Joint Strike Fighter competition may lead Boeing to reassess its participation in the fighter market and its teaming arrangements with other firms, with the possibility of getting out of the manned fighter production business after 2014. Therefore, Boeing is concentrating substantial engineering and development efforts, under contract from DoD, on an Unmanned Combat Aerial Vehicle (UCAV) and associated technology.

Northrop Grumman seeks to acquire TRW in order to become the second largest U.S. defense corporation, which would leave the U.S. with four major defense contractors: Northrop Grumman, Lockheed Martin, Boeing and Raytheon. We believe the merger could start a new wave of consolidation in the industry if smaller companies start to consider mergers, or if other bidders for TRW emerge. Operations in Afghanistan have confirmed the effectiveness (under some conditions) of sophisticated long-range weapons and unmanned drones. These trends confirm the wisdom of the long-range strategy that Northrop Grumman has pursued for the past five years – to become *the* information and sensor company best positioned to provide "transformational" technology on both manned and unmanned systems.[46] Northrop Grumman's products cover current fighters and future unmanned vehicles. Thus, while Lockheed Martin appears to be in the strongest short-term position (based on manned fighters), Northrop Grumman appears to have adopted a more "transformational" strategy (for UAVs and UCAVs) for the long term.

Although overcapacity is a characteristic of the sector now, two opposing factors will converge to affect U.S. capacity to produce greater quantities of fixed-wing military aircraft in the future. As U.S. production eventually focuses on the F-35 beyond 2014, Lockheed Martin will become the only manned fighter manufacturer while Boeing focuses on other sectors. Thus, U.S. capacity to surge manned fighter production will hinge upon Lockheed Martin's post-2014 plant and tooling capacity on the F-35 line. F-35 production, like that of the F-22, relies on computer aided design and production, thereby requiring less heavy tooling and manpower. In addition, Lockheed's F-35 production line is modeled after BAE's Eurofighter *Typhoon* line, which includes standardized, modular and reconfigurable tooling. F-35 surge capacity, therefore, should be greater, more efficient and easily expandable among international partners.

The USAF is encouraging EADS/Airbus to compete to build replacement tankers for the KC-135. As noted earlier, Boeing has submitted a proposal to build 100 KC-767s and then will again compete with EADS in the next lease/buy projected for 2005. The USAF could buy an Airbus derivative to sustain competition and lower costs, or it could lease the Boeing KC-767s. In sum, the outlook for U.S. capacity to produce transport, special mission, and aerial tanker military fixed-wing aircraft, following the 2011 completion of the C-17 production run, is uncertain.

ROTORCRAFT

The rotorcraft industry produces helicopters and tiltrotor aircraft for several markets, including military, foreign military sales, corporate transportation, police department support, offshore oil support, medical evacuation, logging, and other commercial or civil applications. The helicopter sector is highly internationalized and interdependent with five major prime contractors that account for over 91 percent of the industry's market value: Sikorsky, Bell Helicopter, and Boeing in the U.S., and Agusta Westland and EADS Eurocopter in Europe. Sikorsky is a subsidiary of United Technologies Corporation (UTC) producing primarily military helicopters, and filling a segment of the civil market with the S-70, S-76 and S-92. Bell is a subsidiary of Textron with a balance between the military and civil market. Though also upgrading the H-1 helicopter series for the USMC, Bell has mortgaged its future on tiltrotor technology with V-22 for the military and Bell Agusta BA609 for the civil market. Boeing Rotorcraft, a

part of Boeing Aircraft and Missiles Division, produces military helicopters almost exclusively. Agusta Westland and EADS Eurocopter each have strong entrants in the light to medium lift categories.[47] Other countries such as Russia, Japan, Malaysia, India, South Africa, and China produce rotorcraft, but are not significant global competitors.

Current Condition. In the U.S. and Europe, the rotorcraft industry can best be characterized as technologically mature but unstable in structure due to overcapacity in its manufacturing sectors resulting from too many prime manufacturers competing for too limited business. Consolidation and/or teaming arrangements continue to be the answer to ensure growing profitability in a limited market. European prime manufacturers have had some recent successes in this area. In late July 2000, GKN's Westland and Finmeccanica's Agusta merger proved to be a genuine success for the two struggling manufacturers. With a forecasted market share of 13 percent, they've managed to become a viable world competitor with their EH101 helicopter. Agusta Westland took further steps by teaming with Lockheed Martin to bring their EH101 into the American marketplace as the US101. This venture, if successful, will certainly provide Agusta Westland with a leveraged foothold in the large U.S. military market.

Another European teaming success is the cooperation between France, Germany, Italy, and the Netherlands with the production of the NH-90. This high-tech helicopter, jointly developed by Agusta (Italy), Eurocopter (France and Germany), and Fokker (Netherlands) under the guidance of NH Industries and NATO Helicopter Management Agency, has captured the majority of the NATO light-medium lift requirements for the near future. NH-90 is the largest joint helicopter program ever launched in Europe with 25 percent of the production investment being self-financed by the four national industries.

In the tiltrotor sector, the Bell-Boeing MV-22 – the only tiltrotor aircraft, military or civilian, currently in production – is emerging from a directed pause from flight. Reeling from two major crashes in 2000 that killed 23 Marines, the MV-22 acquisition program was halted by the Commandant of the Marine Corps at the end of that year in an effort to closely examine all aspects of the program. Scrutinized at unprecedented levels, the MV-22 was examined by both a Blue Ribbon Panel of senior military and commercial executives and a NASA panel of industry, academia, and government experts.[48] Both boards reported favorably for the aircraft and found that "there are no known aeromechanics phenomena that would stop the safe and orderly development and deployment of the V-22."[49]

Though the U.S. dominates military tiltrotors, civilian tiltrotor development is spread between the U.S. and Europe. The BA609, a seven to nine passenger civil tiltrotor joint venture between Bell Helicopter Textron (75 percent) and Agusta Westland (25 percent), is undergoing initial ground test and development. Bell and Agusta Westland officials have estimated a worldwide civil tiltrotor market of at least 1500 aircraft.[50] However, the BA609 has been the subject of delays and setbacks, and now Bell has publicly admitted that further aircraft development and civil certification awaits successful V-22 testing.[51]

No other serious large-scale civilian tiltrotor development is being pursued in the U.S.[52] In Europe, EADS Eurocopter has begun the concept development phase of a 20-passenger tiltwing aircraft to compete, as "something more advanced than the Bell Agusta 609" and as a proposal to fulfill the European Commission's Fifth Framework

research program.[53] Though considerably scaled down from Europe's tiltwing program predecessor – the "2-Gether" program – the research into critical tiltwing technologies is still estimated to cost 40-60 million euros, half funded by industry and half by the European Commission.[54]

Challenges. The world rotorcraft industry faces at least four major challenges. The first is to develop partnerships and teaming arrangements to sustain the companies that are supporting the rotorcraft sector. An example, beyond the previously discussed NH-90 in Europe, is the Boeing and Sikorsky partnership for development of the Comanche for the U.S. Army.[55]

The second challenge is to find the resources to invest in research and development (R&D) to improve future technologies that can reduce operations and support costs of rotorcraft while increasing range, payload, and speed. Recent reductions, particularly in the U.S. for rotorcraft R&D at NASA, will require either more funding at the corporate level or, more appropriately, an increased R&D commitment from the federal government.

The third challenge is overcapacity. It is a defining issue in the U.S. while remaining the number one concern among the European competitors. For example, although Agusta Westland has projected record sales in upcoming years, they've recently reported closing one of their production facilities, cutting 950 jobs, and consolidating operations in order to remain competitive in the world market. Even though there has been a reduction in the number of prime vendors in Europe, a sluggish civilian market and constrained military budgets are certainly key contributors to Europe's overcapacity problems. However, partnerships, limited productions, and licensing in foreign markets decrease costs, increase production efficiencies and raise overall profitability. Additionally, lowering cost structures, improving existing product lines, and concentrating on increasing after-market services are helping to overcome overcapacity.

Finally, rotorcraft manufacturers, as with others in the aircraft industry, are plagued with the growing concern of their aging workforce. Within the next fifteen years, the industry's highly skilled engineering and manufacturing workers will be retiring with limited skilled replacements available to take their place. To ensure relevance in the future market place, we believe these leading manufacturers, in close cooperation with their unionized work force, must now make capital investments in their workforce through aggressive recruiting programs, training plans, and incentive options.

For the V-22, the USMC and U.S. Naval Air Systems Command have designed a recovery program leading to test flights resuming mid year 2002. A restructured joint program office is coordinating a four-phase plan of block modification.[56] The Pentagon has requested $1.99 billion for only 11 V-22s (nine MV-22s for the USMC and two Special Operations CV-22 versions) in the fiscal year 2003 defense budget. This small number of V-22s is considered the minimum to support the industrial base at Boeing and Bell.[57] Even if such low production rates are enough to sustain the prime manufacturers, they will inevitably lead to increasing overall program costs and sub-vendor difficulties. However, if recent mid-winter layoff announcements of 1,500 to 2,000 people at the Boeing plant in Philadelphia and 275 workers at Bell Helicopter Textron's Fort Worth plant are any indications, even the prime manufacturers will not escape the ramifications of the slowdown.[58]

Outlook. Military rotorcraft markets show increased expansion while civilian markets remain constant. The ten-year world demand for the rotorcraft industry is expected to rise, with production and major modification programs totaling over 9,500 airframes worth over $75 billion. This forecasted market increase includes 4,800 civil airframes worth $12.4 billion and 4,700 military aircraft worth $62.6 billion (a resultant market share of 20 percent civilian and 80 percent military). The procurement of new airframes and aggressive rebuild programs in the U.S. and European military markets will account for the largest segment of growth.[59] However, with few new rotorcraft in development (e.g., V-22 and RAH-66), the military sector, particularly in the U.S., is primarily focused on efforts to remanufacture the current fleets of aircraft, extending their lifecycles for another twenty years.

The notable exception to this remanufacturing trend is the recent award to Sikorsky for 269 new MH-60R multi-role helicopters for the USN. In this case, excessive wear of the original SH-60 airframes led the USN to decide that new manufacture was more cost effective than remanufacture. It will be interesting to note, as other service remanufacturing programs approach execution, whether those programs switch to the USN's chosen path as well.

North American operators expect to replace over 11 percent of their existing fleet, in addition to a small growth in size of 2.8 percent. Approximately 55 percent of these new helicopters will come from North American manufacturers while European consortiums will supply the other 45 percent. Europe will likely replace over 16 percent of its existing fleet and only expand by 3.3 percent in new aircraft. But 75 percent of the new aircraft will come from European-built consortiums. Additionally, a nearly 10 percent growth in airframes is expected from the emerging markets in Asia, Africa, and the Mideast, as 17 percent of their existing fleets are replaced.[60] The strongest sector of these markets likely will be in multi-engine turbine helicopters, due to their increased capability and safety considerations in the commercial sector.

Additionally, we believe the post-September 11 security environment suggests a boost to the civil and military markets for rotorcraft in support of Homeland Security. Though not yet evident in the order numbers, increased usage of current law enforcement fleets, combined with increased budgets for anti-terrorism campaigns, should lead to expanded requirements for new rotorcraft. New aircraft may be law enforcement's only choice since a historical resource for such rotorcraft – the U.S. military – has a fleet of aging platforms with virtually no available surplus.

The civil market in China is particularly noteworthy. Outside of the Hong Kong area, there are very few civil rotorcraft operating in China. The geography and population of the country present an enormous market potential and any company breaking into that region could position itself for a significant competitive advantage. In the shorter term, as U.S. and European markets mature, Pacific Rim and Latin American countries will become potential growth areas and may present the next battleground for market dominance. We project that system designers and integrators will assume primary roles in the development of new rotorcraft as customers become more concerned about avionics and onboard systems capabilities rather than flight platforms. Today's platforms are often secondary to the increasingly complex systems they carry.

In the U.S. Marine Corps, replacement plans for aging legacy platforms and emerging operational concepts such as Expeditionary Maneuver Warfare have been

inextricably tied to the successful fielding of the MV-22. Operations in Afghanistan have underlined the challenges faced by helicopters in such a high-altitude, rugged environment, often operating at long ranges. Some of those problems would, arguably, be better handled with a V-22. To that end, the USMC, and to a lesser extent the U.S. Army, have expressed interest in a heavy-lift tiltrotor aircraft – particularly Bell's conceptual Quad Tiltrotor (QTR). Though Bell claims to be able to produce a QTR to by the end of the decade and the federal government has contracted with Bell for a $6 million feasibility study, current difficulties with the V-22, combined with competing resources in the Pentagon will probably delay any advanced development of such an aircraft.

The V-22 program is the master of its own fate. If the next round of testing is successful, nacelle design problems are effectively solved, and reliability is improved over its last operational test results, the USMC and U.S. Special Operations Command will field the V-22. On the other hand, if the program has one more significant challenge the Services will likely go to Sikorsky or Agusta Westland for an alternative medium lift helicopter. Combined with the cost overruns and delays Bell Helicopter Textron has accumulated with the H-1 upgrade program, a subsequent decision to cancel the V-22 would likely destabilize the military side of the company or make it a candidate for merger or acquisition. We believe the only other likely path for Bell would be a quick teaming with Lockheed Martin and Agusta Westland, if the option is available, on the US version of the EH101. This would present the then-renamed US101 as a possible medium-lift alternative for the USMC.

Consolidation has been present in the fixed-wing industry for years and it may be time for rotorcraft to do the same. EADS Eurocopter and Agusta Westland in Europe are in solid shape, yet the top three manufacturers in the U.S. present significant overcapacity, and at least one will likely have to merge. We believe it is difficult to predict a market share sufficient for each of the three to sustain current capabilities. To ensure future survival, the remaining rotorcraft manufacturers will then have to size their capacity to match reduced demand, expand their modification and remanufacturing capabilities, and pursue rotorcraft logistics services.

JET AIRCRAFT GAS TURBINE ENGINES

Four companies – General Electric (GE) and Pratt & Whitney (P&W) of the United States, SNECMA of France, and Rolls-Royce (RR) of the United Kingdom – continue to lead the engine sector. The aircraft engine market is highly competitive and sized by the number of airframes built. Orders and sales of aircraft equate to orders and sales of engines, spares and services. Also, the level of activity of the airliners and the military aircraft (i.e. operations tempo, flying hours, type of missions, deployments, etc.) drive the demand for spare parts and services, which are critical sources of revenue in the engine industry.

Current Condition. The highly competitive engine market is pushing companies to increase efficiency, consolidate operations, develop innovative marketing approaches and cut profit margins. Companies' R&D efforts are directed into improving performance, production techniques, and management systems in order to improve their competitive advantage.

After several years of flat demand in the military engine market, due to global reductions in defense expenditure and downsizing of military aircraft market, the prospects for the future are for increased demand. The decision to develop the F-35, the projected increases in the U.S. defense budget and the increase in military activity after September 11 will significantly increase the demand for both new engines and spare parts.

In the civil sector, the near-term concern is surviving the post September 11 damage to the industry and developing/implementing those plans necessary for recovery. Internationally, every quantifiable indicator of the engine industry's health has decreased from previous years: orders, backlog, shipments, sales, profit margins and production all contracted. Of note, engine imports jumped 31 percent, or $1.2 billion to $4.9 billion in 2001, an indicator of the internationally competitive nature of the civil engine market.[61] For civil engine manufacturers, the ability to weather a depressed industry for one to two years as a result of the cancellation or postponement of commercial transport orders and deliveries is paramount to their survival.

In addition, while engine manufacturers consistently meet military and civil requirements by providing high quality engines that are reliable and cost effective, a significant strategic trend is the increasing globalization of the industry, wherein multiple prime and subcontracting agreements are made across international borders. For the U.S., this raises concerns with regard to productive capacity and mobilization in which little, if any, control can be exerted over non-American suppliers and manufacturers when needed. The U.S. government and the aircraft industry must remain cognizant of these concerns and take those actions necessary to ensure that the greatest freedom of action is maintained in the production of those systems that are deemed strategically important.

Challenges. The main challenge facing engine producers is the requirement to maintain overall profitability in the post September 11 environment. The current rise in DoD sales will not be enough to offset the decline in civil sales. At greatest risk are those engine manufacturers that lack the market share and diversification necessary to remain profitable, which may result in further consolidation of the industry. Indeed, the near-merger between GE and Honeywell and the publicly expressed interest by GE in purchasing 20 percent of SNECMA are indicative of future trends in consolidation wherein larger engine manufacturers seek to increase their overall industrial strength by consuming their smaller competitors.

Outlook. As the world slowly returns to air travel, a degree of stability will return to the industry. In particular, the engine sector's future hinges on a number of key DoD programs that the war on terrorism has accelerated and the ability of manufacturers to maintain short-term viability on the commercial side.

In spite of the near-term health of the military side of the industry, the long-term prospects for military engines are not promising. Fighter aircraft production in the U.S. will eventually shrink to only one aircraft, the F-35. The possible shift to UAVs and the multibillion-dollar cost of developing new military engines can jeopardize the industrial base for fighter engines in the U.S. Given the possible consequences, companies might abandon the unique military market and focus exclusively on commercial engines. There are significant risks involved in developing the new generation of fighter engines, but there is also risk in having the F-35 and F-22 rely on the same engine (F-119 and its derivatives). That, coupled with the need to control prices through competition, leaves

the U.S. with the requirement to keep both GE and P&W in the military fighter engine business. Therefore, government support for the development of both the F-135 by P&W and the F-136 by GE, and splitting the F-35 engine production between the two companies is essential.

Ending the production of current generation military engines in the U.S. will erode the capability of the industry to support surge needs during war and will result in higher costs for spare parts and services. A possible solution for sustaining the industrial base will be reengining aging military aircraft (i.e., C-5 reengining) and helicopters. Given the increased operations tempo in future years and the need to continue to fly these aging airplanes, reengining would benefit both the industry and the military. Further, we believe that future engines for military helicopters and transports should be based on commercial designs. Using the same engines for military and commercial use, with minimal modifications, will provide an adequate solution for the military without excessive government expenditure.

For the civil sector, recovery from September 11 is occurring at an unpredictable pace. Maintaining profitability during the recovery will be easier for the larger, more diversified engine manufacturers than for the smaller ones. Engine maintenance, operational support, information services, financing, engine leasing and aircraft trading are but a few of the areas that engine manufacturers are pursuing as a means of diversification. Civil engine orders and sales will slowly increase in the short-term, as the effects of September 11 wear off and aircraft orders and sales slowly increase. This will parallel the recovery in the U.S. economy already underway and rely upon future stability in fuel prices. In the meantime, the current environment is ripe for further engine manufacturer consolidations. Short of consolidation, engine manufacturers will continue to form partnerships to reduce competition, risks and costs; and to identify, exploit and increase future markets and market share. As an example, the long-standing partnerships of CFM International (GE and SNECMA) and International Aero Engines (P&W and RR) have recently been joined by the "Engine Alliance" of GE and P&W in the development and production of an engine for the A380. In the long-term, the outlook is good; with predictions of civil engine sales over the next 20 years reaching 71,400 new engines totaling $415 billion.[62] We project that the highest stakes battle in the engine markets will be fought for new transports (A380 and Sonic Cruiser) and the follow-on to existing narrow-body commercial transports (A320 and B737).

Overall, the engine manufacturing industry remains capable despite the intense competition and short-term setbacks associated with September 11. Future partnerships and consolidations can be expected in a manufacturer base capable of meeting the strategic requirements of the aircraft industry.

GOVERNMENT: GOALS AND ROLE

Historically, U.S. policy regarding the aircraft industry was laissez faire by international standards. Direction was largely set by the businesses that comprised the different sectors, with the government stepping in to assist only in times of crisis. With the advent of a new administration and the events of September 11, it appears the government will be more active in guidance and assistance, as passage of the Air Transportation Safety and System Stabilization Act and the Aviation and Transportation Security Act[63] demonstrate. In the latter, the legislation will assist the airlines and

strengthen aviation security by federalizing airport security forces, deploying air marshals with flights, and improving airport perimeter access security.

As part of the change, the FAA is transitioning security operations and research to the Transportation Security Administration (TSA) and working to build a safe and efficient national airspace system. While air traffic is still below the levels seen before September 11, the FAA is beginning to see traffic returning to pre-September 11 levels and is focusing on making needed investments in infrastructure.[64] The TSA plans to study security procedures at selected U.S. airports, the result of which will be security improvements at all 429 U.S. airports with commercial service.[65]

As noted earlier, the U.S. government has attempted to assure the continued health of the jet engine sector by demanding competitive bidding continue for future military contracts. Similarly, the U.S. government has advocated the need for sustainment of research and development and defense procurement, though much of this is slated for ballistic missile defense. Both developments demonstrate an active governmental interest in maintaining U.S. competitive advantage in aerospace and aircraft.

Similarly, the federal government continues to seek opportunities and markets for the commercial transport sector. In January 2002, the Department of Transportation tentatively approved antitrust immunity between certain American and British airlines, with conditions. The effect will be to expand service to U.S. cities and encourage price competition.[66] The U.S. has signed similar "open skies" agreements that eliminate restrictions on how often carriers can fly between the countries, the kind of aircraft they use, and the prices they charge, with 56 countries, including 21 in Europe.[67]

The U.S. still lacks a clearly articulated strategy designed to sustain the U.S. aircraft industrial base and enhance long-term global competiveness. Nevertheless, progress has been made in quantifying the impact of the aircraft industry on the U.S. economy, due mainly to the disastrous after effects of September 11. Investment in basic, long-term research and development can restore U.S. leadership in advanced aerospace technology development. Support to universities, as well as to national and defense laboratories, has been proposed that will focus on basic science and development of new capabilities. Recent legislation has also been put forward to develop technology to produce cleaner, quieter, more efficient aircraft.[68] Changes to business structure, including planning and programming, acquisition, Congressional oversight and coordination with the Office of Management and Budget, have been recommended to improve responsiveness and agility. Government leaders are pursuing active strategies to protect and accelerate the aircraft industry.

CONCLUSION

Even in the wake of the terrorist attacks on September 11, the U.S. aircraft industry continues to be a bulwark of American national power. While some sectors are still in a state of uncertainty, others have found firm ground and are gaining strength. With the downsizing and consolidation of recent years, some airlines were better postured to withstand revenue losses. Nevertheless, the air transport sector is depending heavily on the recovery of the U.S. economy to return to profitability. On the military side, the U.S. defense budget shows promise for a new period of growth and innovation, particularly in unmanned platforms. Industry strategies will increasingly involve

transnational partnerships that share risk, improve interoperability and promote economies of scale.

History has shown that today's industry slowdown is temporary. The attacks of September 11 deepened and accentuated a downturn in the cyclic market for commercial aircraft and engines. It will take longer to recover, but there is an opportunity to "right size" for the immediate future. Despite the setbacks in 2001, the U.S. aircraft industry remains competitive and capable of meeting current national security requirements. As the economy regains strength and the market demand approaches its next cyclic upswing, the industry must work toward achieving a balanced market share among competitors, especially as the U.S. dollar continues to remain strong and European manufacturers continue to enjoy a price advantage over U.S. manufacturers, due to euro/dollar exchange rates. Only a combined effort by industry and the government can preserve and enhance this key U.S. industry so crucial to our national power.

Additional Essays

Nanotechnology in the Aircraft Industry

Lt Col Barry Coble, USAF and Mr. Douglas Burke, United States Secret Service

The FAA commissioned the Industrial College of the Armed Forces Aircraft Industry Study to investigate the current state of nanotechnology research and development and subsequent implementation in the aircraft industry. Nanotechnology involves the nanoscale science and engineering encompassing the systematic organization, characterization and manipulation of matter at atomic or molecular levels. Research involved discussions held with major airframe and aircraft parts manufacturers in the United States, United Kingdom, and France, attendance at two conferences devoted to recent nanotechnology developments, and library searches of the most recent applicable literature

Active, ongoing nanotechnology research by U.S. aerospace companies is nearly non-existent. Some companies are watching the field and are preparing to pursue research targeted at aircraft manufacture. However, most are taking a wait-and-see attitude and have no plans to incorporate nanotechnology research into their overall strategy. Reasons for this stance vary from "it's too far in the future" to the fact that they are willing to simply monitor government research in this area for now. The majority opinion is that nanotechnology research has not advanced to the point where it can be applied economically and practically in aircraft production.

Many European aerospace companies, on the other hand, are conducting active research into nanotechnology applications. Those that are pursuing such research are doing it in conjunction with universities. While none would provide details of the research, they did mention pursuing niche applications along the lines of nanomaterial research (new aircraft building materials) and nanocomputing research (new computer chip-making material). European companies, on the whole, feel that nanotechnology will increase competitiveness and profitability in the future.

The study concludes with recommendations for further research and proposals for the FAA to spur U.S. aerospace corporation efforts in nanotechnology.

Analysis of World Class Supply Chain Management For Defense Logistics Agency
Mr. Bob Szerszynski, Dept. of Army, CDR Charlie Ray, USCG, and Mr. Dan Bowman, Dept. of Air Force

This study centered on identifying the key process characteristics that constitute a "world class" aircraft life-cycle support base and to determine which, if any, and to what degree original equipment manufacturers (OEMs) are developing or have incorporated those process characteristics. Our review included both domestic and foreign commercial segments, as well as foreign military segments of the aircraft life-cycle support industry. The study sought to identify methods/practices used by OEMs to develop and manage an aircraft support base and to correlate/compare those methods/practices with those employed by U.S. DoD aircraft support agencies. The study also included analysis of key process characteristics to determine which might be most suitable for use within the DoD. We concluded with recommendations for implementation.

The Council of Logistics Management defines Supply Chain Management (SCM) as "the systemic, strategic coordination of the traditional business functions and tactics across these business functions within a particular company and across businesses within the supply chain for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole." The reduced number of major aerospace defense contracts, the mergers of aerospace corporations, and the cyclical downturn of the civil market have placed tremendous pressure on the remaining aerospace OEMs to address inefficiencies within their supply chains. For similar reasons, all of the aerospace OEMs interviewed are actively pursuing what they consider the largely untapped revenue potential available in the aftermarket services business. While all the OEMs interviewed intended to base their business case as a service provider on excellence in Supply Chain Management (SCM), relatively few of those interviewed have reached a World Class performance level. Those that are most successful now and who have the highest probability for realizing future revenue growth from the service markets share three primary strategies. First, they are actively engaged in identifying strategic suppliers, solidifying their relationships with these suppliers and reducing the separation between the suppliers and end users. Next, for their commodity suppliers, they are aggressively forcing competition and eliminating inefficient vendors while concurrently pursuing cycle time reductions for every phase of the spares procurement and distribution processes. Finally, they recognize that excellence in Information Technology (IT) is a strategic advantage and are trending away from proprietary systems and towards common standards and open access usually provided by a third party vendor or off-the-shelf systems.

The Future Transport Rotorcraft and the Quad Tiltrotor: The Future of Heavy Lift for the Services?
Lt Col Curt Haberbosch, USMC

The future of heavy lift rotorcraft for the U.S. Armed Services is on a somewhat convoluted and confusing path. It involves the Joint Staff as well as several branches of the Services, presents conflicting timelines and priorities, and promises a murky road

ahead for the companies that produce heavy lift aircraft. Future heavy lift replacement options continually compete (usually poorly) within DoD with other high-priced acquisition programs – all within a particularly constrained fiscal environment. Even so, some interesting and possibly viable alternatives have arisen that present promise for commonality, capability, and even life cycle cost savings. The two platforms/concepts being given greatest consideration are the Army's Future Transport Rotorcraft (FTR) and Bell Helicopter Textron's Quad Tiltrotor (QTR).

On the industry side, Sikorsky with its CH-53E, and Boeing with the CH-47, are the only two companies currently in the heavy lift helicopter business. With its aggressive marketing of the QTR, however, Bell Helicopter has demonstrated its desire to join this small group. If paired with Boeing, as it has done with the V-22, Bell would have an even stronger chance of market entrance success (assuming successful reemergence of the V-22).

Nonetheless, heavy lift aircraft for the Services – particularly the Marine Corps and the Army – appear to be at a crossroads. Great capabilities are promised with the proposed future heavy lift rotorcraft. On paper, aircraft like Bell's Quad Tiltrotor are able to lift enormous amounts of troops and equipment over long ranges, to self-deploy to distant locations, and to rapidly build up combat power ashore. While presenting commonality on the one hand, they show promise for growth in the future. However, many issues remain with regard to funding, Service compatibility, timing of fleet introduction, and even with requirements. The Joint Staff and the Services must continue to discuss the future of heavy lift rotorcraft development and determine the possibility for future commonality and life cycle cost savings that a joint platform could provide. The FTR, whatever it becomes, may well be the future heavy lift replacement, but if it is, it must be reconciled with the Joint Common Lift platform operating capabilities agreed to by the Services during the Overarching Rotorcraft Commonality Assessment. All of this will take funding and time to develop and to manufacture the technologies required for success of such platforms. Money for future heavy lift is at a premium, even in these turbulent times. Aviation priorities that are already well established (e.g., RAH-66, V-22, F-35, F-22) leave little room for others. And now, with current homeland security needs pressing, it will be even more difficult to address a plan for heavy lift rotorcraft. Nevertheless, a plan must be made and the funds applied to ensure success for the Services' needs of the future. These issues are examined in depth in this report.

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[3] U.S. Congress, "Air Transportation Safety and System Stabilization Act," September 22, 2001. 107th Congress, 1st sess. 2001.
[4] Carol B. Hallett, "State of the U.S. Airline Industry," Air Transportation Association, 6 March 2002, 1.
[5] Gregory Polek, "New Door Rules Leave Many Regionals Riled," Aviation International News, February 2002.
[6] Hallett, 4.
[7] Ibid.
[8] Ibid. In June 2001, airline orders and options were 955 and 1,663 respectively, but those figures fell to 844 and 1,195 as of December – a total loss of 111 firm orders and 468 options.
[9] Teal Group Corporation, "World Military and Civil Aircraft Briefing," October 2001, 3.

[10] The Boeing Company, "Boeing Web Site: Revenue By Market Segment," http://www.boeing.com/companyoffices/aboutus/overview/overview_html/sld007.htm.
[11] Teal Group Corporation, 4.
[12] Ibid., 6.
[13] Ibid.
[14] Matthew Lynn, Birds of Prey (New York: Four Walls Eight Windows, 1997), 225. However, the bill did not become law.
[15] Teal Group Corporation, 4.
[16] David Bowermaster, "Fourth Round of Boeing Layoffs," The Seattle Times, 18 January 2002, 2.
[17] Andrea Rothman, "Airbus Foresees 60 Percent Decline in Aircraft Orders for 2002," Seattle Times, 4 January 2002.
[18] Mike Iswalt, "Global Aviation's Bleak Outlook," The Dismal Scientist, 8 November 2001.
[19] Teal Group Corporation, 7.
[20] Ibid.
[21] Rothman.
[22] Keith L. Alexander, "A Move To Redefine Advance," Washington Post, 13 March 2002, E01.
[23] Boeing Corporation News Release, 4 December 2001.
[24] Federal Aviation Administration Office of Airport safety and Standards, "The Operational and Economic Effects Of New Large Airplanes On United States Airports," March 30, 1998.
[25] Aerospace Industries Association, 8.
[26] Ibid., 26.
[27] Ibid., 31.
[28] Ibid., 8.
[29]Boeing Web Site; http://www.boeing.com ;Lockheed Martin Web Site, Sales by Customer http://www.lmco.com.
[30]U.S. Congress. Senate. Committee on Armed Services. *Statement of Commander in Chief, U.S. Transportation Command, before the Senate Armed Services Seapower Subcommittee on Strategic Airlift and Sealift Imperatives for the 21st Century, 26 Apr 2001*. 107th Congress, 1st sess., 2001.
[31]Ibid. "The USAF has even begun assigning two C-5 aircraft to its priority missions to better ensure mission accomplishment."
[32] "Lockheed Martin selects General Electric as engine supplier for C-5 RERP," Aerotech News and Review, 8 August 2000, http://www.aerotechnews.com/starc/2000/080800/GE_C5.html.
[33] "South Korea Picks Boeing in Fighter Deal," New York Times, 19 April 2002. Deliveries are expected between 2005 and 2009.
[34]Air Force Technology Web Site, "Industry Projects," Net Resources International Ltd, London, United Kingdom, http://www.airforce-technology.com/projects/t45/).
[35] "Handy: Pentagon Needs 222 Boeing C-17s," Bloomberg.com, 25 February 2002.
[36] Teal Group Corporation, Teal Group World Aircraft Overview, "World Military and Civil Aircraft Briefing", September 2001.
[37] Ibid.
[38] "USAF Pressures Airbus to Stay in Competition," Aviation Week and Space Technology, 15 April 2002, 47.
[39] Northrop Grumman Corporation Website, http://www.northgrum.com.
[40]U.S. Congress. Senate. Committee on Armed Services. *Report of the Under Secretary of Defense (Acquisition, Technology and Logistics) to the Committee on Armed Services, "Military Aircraft Industrial Base/JSF Teaming," 4 February 2002*. 107th Congress, 2d sess. 2002. UAVs/UCAVs are part of the future of the industry. The Air Force's top general wants a more powerful version of the Predator UAV to perform as a dedicated hunter-killer that would shorten the time between detecting and hitting a target. Chief of Staff Gen. John Jumper said the Predator B, manufactured by General Atomics Aeronautical Systems, Inc. represented "the next generation" in the development of armed UAVs. See "Jumper Bullish On Predator," Defense Week, 25 February 2002, 6.
[41] The U.S. government does not participate in offset programs.
[42] "Analysts See Gripen Win in Hungary as Pointing to Need for JSF," Defense Daily International, 14 September 2001.

[43] For the international customer, this is as much about perception as reality; the F-16 Block 60 is certainly state of the art, but F-16s have been in service for over 20 years. The "production gap" is a conscious decision by the USAF and USN. After years of studying options, the USAF decided in 2002 to run a higher level of operational risk when hundreds of F-16 fighters retire from the fleet in coming years. Alternatives to mitigate a shrinking combat aircraft fleet -- none of them deemed attractive -- were to buy new aircraft or extend the lives of planes in service. To compensate for a 100-aircraft deficit in 2010, the USAF will rely on the greater capabilities of the F-22. The USAF expects the F-22 to attain initial operational capability (IOC) in 2006, but cannot ramp up production to cover the shortage of F-16s aircraft-for-aircraft. The USAF hopes the F-22's qualitative improvement over the aircraft it replaces will offset the dip in fighter quantities that will span at least four years. In 2008, when the anticipated shortfall begins, the first F-16Cs off the production line in 1982 will turn 26 years old -- an unprecedented age for fighter retirement. With each passing year, some 120-180 more F-16s will turn 26 years old and face retirement. The aircraft's replacement, the JSF, will just begin introduction into the fleet at that time, attaining IOC in 2011. (Lt Gen Joseph Wehrle, "Air Force to Accept Greater Risk as F-16 Fleet Shrinks in Coming Years," Inside The Pentagon, 28 Feb 2002, 1.) Naval aviation was under stress before the current conflict. Particularly affected are the USN's limited special mission aircraft, such as the EA-6B Prowler, the EP-3E Aries II signals intelligence aircraft and P-3C patrol aircraft. Higher usage rates result in adverse effects on service life and maintenance costs. The result is that more than 300 aircraft will require service-life extensions earlier than planned or budgeted. Fixing the aircraft problem will not be easy. The USN -- despite requesting $323 million more for aircraft procurement in FY03 -- will buy fewer aircraft than this year. As previously, the Navy will fall far below the 190-210 aircraft production level it needs to replenish its inventory. Per SECNAV England: "At the present time, given the age of its aircraft, the USN would place a higher priority on increasing aircraft procurement rates over ships." In particular, the USN would like to buy more than the 44 F/A-18E/Fs it asked for. Its goal has been to buy at least 48 of the strike fighters annually. ("War Drains U.S. Military's Aircraft And Munitions," Aviation Week & Space Technology, 18 Feb 2002, 31.)

[44] "Key Lawmaker Warns DOD Headed for Financial Disaster in Five Years," Inside The Army, 11 March 2002, 4.

[45] "Lockheed Moves Resources To Drone Development After Afghanistan," Bloomberg.com, 26 February 2002.

[46] "Defense Industrial Base," The Economist, 9-15 March 2002.

[47] Rotorcraft are roughly categorized by their maximum gross weight as light (up to about 8000 pounds), medium (8000 to approximately 15,000 pounds), and heavy (over 15,000 pounds). Note: Military definitions of these categories are shifted significantly heavier.

[48] Paul Lewis, "Tiltrotor Development," Flight International, 27 November 2001, 19.

[49] John R. Guardiano, "Battlefield Intelligence," Rotor & Wing , January 2002, 24.

[50] Edward H. Phillips, "Bell, Agusta on Track for BA609 First Flight," Aviation Week & Space Technology 155, no. 29, July 2001, 52.

[51] Paul Lewis, "Model 206 Helicopter May be Axed as Bell Told to Cut Costs," Flight International, 13 November 2001, 12.

[52] There are some small-scale development efforts such as the four-engine Xantus tilt-prop kit-build aircraft, but no major programs are being pursued.

[53] Michael A. Taverna, "Europeans Pursue Critical Tiltwing Technologies," Aviation Week & Space Technology, 12 February 2001.

[54] Taverna.

[55] Raymond Jaworowski and William Dane , "2002 AHS International Directory, Vol. 48, No.1," The World Rotorcraft Market 2002-2011, March 2002, 20.

[56] Paul Lewis, "Last Chance for V-22 to Come Good," Flight International, 29 January 2002: 32.

[57] Tony Capaccio, "Sikorsky, Agusta Helicopters Eyed as Options for Osprey V-22," Bloomberg.com, 13 March 2002.

[58] "World News Roundup, Americas," Aviation Week & Space Technology 155, No. 25, 17 December 2001: 22. "Sales Slump, V-22 Troubles Prompt Bell to Cut Workforce," Aviation Week & Space Technology 155, no. 11, 10 September 2001: 38.

[59] Teal Group Corporation, "The Past, Present, and Future of the Rotorcraft Industry", World Rotorcraft Overview, July 2001.

[60] Vertiflite, "The World Rotorcraft Market 2001-2010," AHS International Directory, 2001, 14.
[61] Aerospace Industries Association, "2001 Year-End Review and 2002 Forecast—An Analysis," (2002), www.aia-aerospace.org/stats/yr_ender/yrendr2001_text.pdf., March 10, 2002.
[62] "The Outlook – Engine Demand," (2002). www.rolls-royce.com/civil/outlook/2001/engines/demand.htm, March 3, 2002.
[63] U.S. Congress, "Aviation Transportation Security Act," November 19, 2001. 107th Congress, 1st sess. 2001.
[64] U.S. Congress. House. Committee on Appropriations. *Testimony of Jane F. Garvey, Federal Aviation Administrator, before the House Committee On Appropriations, Subcommittee On Transportation And Related Agencies, concerning the Federal Aviation Administration, March 13, 2002*. 107th Congress, 2d sess. 2002.
[65] U.S. Department of Transportation Press Release 12-02, "Transportation Security Administration To Map Security Procedures At Selected Airports Nationwide," February 1, 2002.
[66] Press Statement by U.S. Department of Transportation Secretary Norman Mineta on Decision by American Airlines-British Airways to Decline Terms of Antitrust Order, 25 January 2002.
[67] U.S. Department of Transportation Statement concerning the signing of open skies aviation agreement with France, 22 January 2002.
[68] U.S. Congress. House. "The Aeronautics Research and Development Revitalization Act of 2002" introduced May 2, 2002. 107th Congress, 2d sess. 2002.